GUIDELINES IN THE ELABORATION OF A TEACHING SEQUENCE OF KINEMATICS ACCORDING TO A HISTORICAL APPROACH

Louis Trudel
University of Ottawa, Canada
E-mail: ltrudel@uottawa.ca

Abdeljalil Métioui
Université du Québec à Montréal, Canada
E-mail: metioui.abdeljalil@uqam.ca

Abstract

The domain of motion or kinematics is important because it forms the basis of mechanics, an important branch of physics. By studying kinematic phenomena in the laboratory, high school students are likely to develop a better understanding of kinematics concepts as well as elements of the scientific approach to study natural and constructed phenomena. However, students encounter difficulties in understanding these concepts, just as in the acquisition of the skills necessary for the accomplishment of the different stages of an experimental process. Therefore, the purpose of this research was to provide guidance, according to a historical approach, which would inform teachers in the design of teaching sequences on the study of kinematics.
Keywords: *conceptual understanding, high school physics education, historical approach, kinematics.*

Introduction

If there is a domain that causes a lot of difficulties to students, it is kinematics, defined as the study of the motion of objects without worrying about its causes. There are several reasons for this. First, students have, before arriving in physics courses, extensive experience on properties of the motion they acquired in their interactions with events of their daily lives. This experience allowed them to build for themselves a set of cognitive schemas to interpret motion phenomena. These schemas are well adapted to the tasks of everyday life: to ride a bicycle, to catch an object, etc. However, they can interfere with learning scientific concepts, especially if the teaching does not take them into account (Trudel, 2005). A second reason for the difficulty of kinematics is about how one teaches it in introductory courses to physics. Indeed, kinematics is often approached using a mathematization which students are not used to. For example, a current pedagogical practice consists in bringing students, at the beginning of the study of kinematics, in the laboratory where they measure different properties of the motion that they then put into graphics. Back in class, they analyze the results obtained and carry out calculations using formulas to get the values of speed and acceleration. However, it seems that students perform these various operations without a real understanding of what they do (Trudel, Parent, & Métioui, 2009).These difficulties are reminiscent of those met by scientists, during the course of history, in the development of new scientific theories. These similarities between the conceptions of students and those expressed by scientists at different times suggest that the history of science can inform us on concept development in students. Thus, a historical approach to teaching science can facilitate the development of scientific skills targeted by the physics program in secondary school.

In the first place, it could be used to favor the acquisition of investigative skills scientist among students. For example, in the study of projectiles, an adaptation from Galileo's original experience (done in 1609) would compare student results to those obtained by this scientist, and so discuss the relative merits of the experimental methods used (Borghi, De Ambrosis, Lamberti, & Mascheretti, 2005). Second, a historical approach would allow the student to situate the process of science development according to different historical and cultural approaches (Monk & Osborne, 1997). In this respect, science teachers can incorporate historical examples to demystify certain prejudices that are negative, especially in the case of physics. Students can develop an understanding of human dimensions associated with the development of science, the nature of scientific knowledge and the impact of technological applications in society. Thus, students will become familiar with the contexts of scientific discoveries that extend well beyond communication of scientific facts. Third, a historical study of scientific discoveries can guide the teacher in designing rich activities, involving different dimensions of scientific activity, thus providing his students with the opportunity to deepen their understanding of scientific phenomena (Mayer & Kumano, 1999). These activities could draw inspiration from problems, experiences and solutions put forth by scientists in their discoveries. Indeed, to realize these, they had to solve problems belonging to several dimensions: conceptual (restructuring), methodological (development of experimental methods to verify theories) and epistemological (the nature of knowledge becomes accessible to reason through dialogue and the test of experiences) (Bertoloni Meli, 2006). Hence, the mastery of these different dimensions is associated with a deep understanding of scientific phenomena (Mayer & Kumano, 1999).

Despite these advantages, there are several obstacles to the use of the history of sciences for educational purposes. Among those, lets mention time constraints associated with program coverage and the difficulty of finding historical resources of quality. In addition, some students may have difficulty to understand the point of view of past scientists. For example, they may consider these scientists (especially those whose theories have been replaced by more modern) as inferior when comparing their modes of thinking to those of today.

Historical Approach in Teaching and Learning Sciences

By inscribing their historical approach of science education according to a constructivist approach, Monk and Osborne (1997) recommended that the construction of scientific knowledge be explicitly part of the educative process. Indeed, it is only by overcoming the obstacles created by the use of their misconceptions that students can develop an in-depth understanding of the motion phenomena and the nature of science. Therefore, it is important that they can reflect and share their knowledge about the kinematics phenomenon under study. In addition, the development of conceptual understanding should be done in parallel rather than being confused with the development history of the kinematic concept, like the parabolic motion. Indeed, the previous conceptions of students look more like a pre-paradigmatic reflection rather than the theories of past scientists. In this respect, it can be emphasized that students are certainly not as thorough and systematic in their interrogations about the natural world than these scientists.

These considerations provide science teachers two more reasons to include the history of science in their practice. First, the historical approach facilitates expression and discussion of students' misconceptions by making them worthy of consideration to their eyes. Indeed, in this approach, it is easier for them to accept the erroneous character of their conceptions if they can find similarities with those scientists from different times. Second, by discussing historical development history of a science concept, the students are in a better position to recognize the inadequacy of their previous understanding and the improvement that constitutes the current scientific conception. By incorporating these constructivist principles to their historical approach, Monk and Osborne (1997) proposed an approach in six phases:

1. During the first phase, the *Presentation*, the teacher presents to students a motion phenomenon (for example, a marble falling down an inclined rail) and discusses with them its properties so as to make it problematic inviting them to make predictions about its behavior.
2. In the second phase, *Expression*, students are invited in small groups to share their own ideas and theories concerning a phenomenon of motion to provide multiple points of view on how it could be explained in an atmosphere of respect and hospitality (Trudel, 2005).
3. During the third phase, the *Historical study*, the teacher introduces a richly contextualized example including, for example, the first ideas expressed about acceleration of a free falling ball or descending an inclined rail, the social and economic context of time, the different theories issued by scientists and some known facts in support of one or the other interpretations. In this phase, the student is encouraged to consider the multiplicity of possible points of view in the study of the phenomenon in order to better understand the circumstances and the reasons that motivated support for a theory rather than another. The information may come from various sources: historical films, vignettes, reproduction of historical instruments, computer simulation of historical experiences (Borghi & al., 2005).
4. In the fourth phase, *Experimentation*, the teacher invites his students to work in small groups to design experimental tests allowing to determine which of the ideas expressed, contemporary (i.e. students) or historical, is "correct". Given the time constraints and from the variety of ideas put forth, it is preferable that collection and data analysis be done using software (Trudel & Métioui, 2010).
5. The fifth phase, the *Scientific Explanation*, allows the teacher to present the modern version of the phenomenon. This version can then be compared to different theories emitted by past scientists and ideas from students. The version scientist must be presented as a possible explanation among the ideas expressed.

6. In the sixth and final phase, the *Review and Assessment*, students work in small groups to compare the "pros and cons" of each idea expressed and realize that, if the scientific version allows to explain the various properties of the phenomenon satisfactorily, the other points of view also possess merits. The student learns to use scientific evaluation criteria to judge the value of an idea or a theory.

Guidelines for Designing a Historical Approach to the Teaching of Kinematics

A historical approach is particularly useful to facilitate learning of kinematics. Indeed, kinematics concepts have developed over a long period of time benefiting from the contribution of several generations of scientists. It is therefore easy for the teacher to bring out the transient character of the ideas expressed on this topic over time, while pointing out that most of these ideas had been in progress in their time. In this respect, such an approach would allow students to better understand how scientific ideas are accepted or rejected on the basis of empirical evidence and how controversy can arise concerning the interpretation of these evidences. Thus, the development, using the historical approach, of a better understanding of the scientific process in a context of discovery of new knowledge, seems related not only with the main skills of the physics program but also with a constructivist approach. These different considerations concerning the study of kinematics according to a historical approach lead one to propose the following guidelines:

1. The activity must demonstrate the complexity of the development of kinematics and the interactions between members of the scientific community to develop a better understanding of the phenomena of motion.
2. The activity must be linked to the framework of the current curriculum of kinematics to make teachers of science willing to use it. In this respect, the activity should aim to link scientific knowledge (products) with processes (methods) who gave birth to them (Monk & Osborne, 1997).
3. The activity must be in harmony with current teaching practices of teachers in kinematics to meet their needs in including the history of science in their teaching while emphasizing its complementary nature to highlight the social, cultural and epistemological aspects of construction of scientific knowledge.
4. The activity should describe the authentic work of scientists in the context of the development of science (Van Driel, De Vos, & Verloop, 2006).
5. Teachers should be sensitive to shortcomings of students relatively to the historical approach of the knowledge development about the motion.

Conclusions

The difficulties that students experience in learning kinematics possess similarities to those encountered by scientists of different eras. Despite these similarities between student and scientist approaches, there are several differences, so that a historical approach does not aim only to simply replicate the path of these scientists. Indeed, unlike scientists, the conceptions students have developed so often unconsciously, in interactions with everyday objects, and their private character was not the subject of any debate that would have allowed them to evaluate their merits. It is therefore important that a historical approach incorporates constructivist principles where students have the opportunity to express their ideas, to discuss their merits with their peers, read the ideas expressed by scientists at different times, verify them with the help of experiments and evaluate them according to scientific criteria.

Thus, a historical approach to teaching of kinematics would allow students to better understand how various theories about motion have been proposed, what were the arguments invoked, what empirical evidence or factual evidence had been provided in support of or against each of these theories. Not only will students compare their ideas to those distinguished scholars but they will also be able to better realize the transitory nature of theories, while situating the development of science in a social and cultural context.

References

Bertoloni Meli, D. (2006). *Thinking with objects: The transformation of mechanics in the seventeenth century*. Baltimore: The John Hopkins University Press.

Borghi, L., De Ambrosis, A., Lamberti, N., & Macheretti, P. (2005). A teaching learning sequence on free fall motion. *Physics Education,* (40)3, 266-273.

Mayer, V. J., & Kumano, Y. (1999). The role of system science in future school science curricula. *Studies in Science Education*, *34*, 71-91.

Monk, M., & Osborne, J. (1997). Placing the history and philosophy of science on the curriculum: A model for the development of pedagogy. *Science Education*, *81*, 405-424.

Trudel, L. (2005). *Impact d'une méthode de discussion sur la compréhension des concepts de la cinématique chez les élèves de cinquième secondaire* [Impact of a discussion method upon high school students' understanding of kinematics concepts]. Thèse de doctorat, Montréal, Université du Québec à Montréal.

Trudel, L., Parent, C., & Métioui, A. (2009). Démarche, cheminement et stratégies : une approche en trois phases pour favoriser la compréhension des concepts scientifiques [Process, pathway and strategies: A three-phase approach to foster understanding of scientific concepts]. *Revue des sciences de l'éducation*, (35) 3,149-172.

Trudel, L., & Métioui, A. (2010). *Conception d'une démarche d'investigation scientifique assistée par ordinateur pour faciliter la transition entre les raisonnements qualitatifs et quantitatifs à propos des phénomènes physiques* [Design of a computer-assisted scientific investigation approach to facilitate the transition between qualitative and quantitative reasoning about physical phenomena]. TICE Med 2010-LIBAN-Baabda, 11 au 14 mai 2010, Université Antonine.

Van Driel, J. H., De Vos, W., & Verloof, N. (2006). Relating students' reasoning to the history of science: The case of chemical equilibrium. In Gilbert J. (Ed.), *Tome 1 - Science Education: Major themes in science education* (pp. 135-150). New York: Routledge.